Georgia Tech | Institute for Electronics and Nanotechnology

National Nanotechnology Coordinated Infrastructure

Sacrificial Polymer use in the Creation of High Performance Circuit Boards

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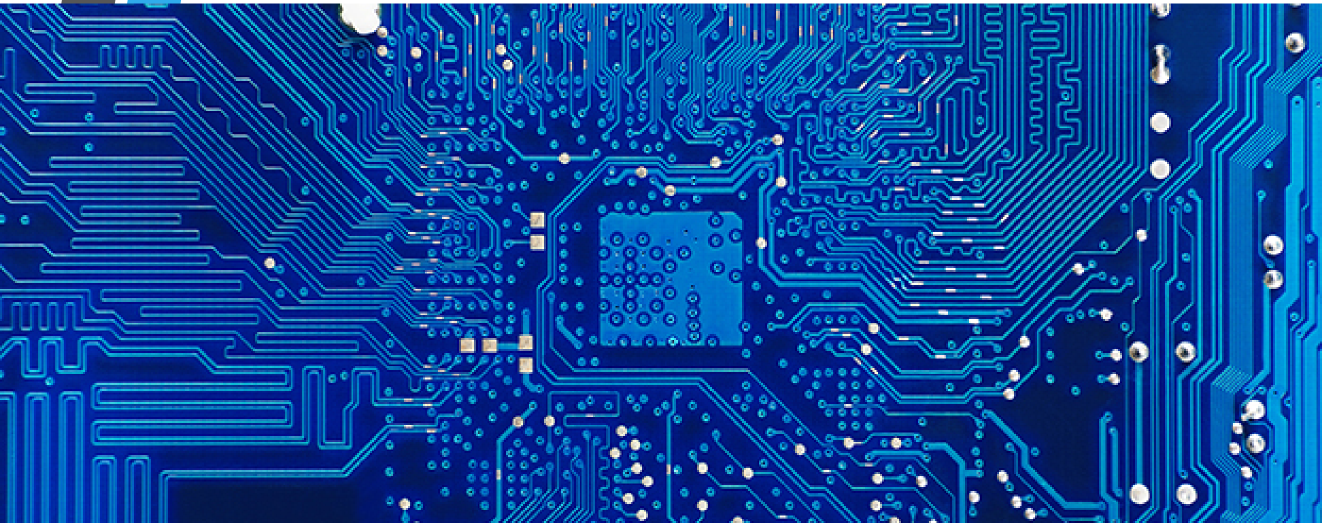
SENIC Southeastern Nanotechnology Infrastructure Corridor

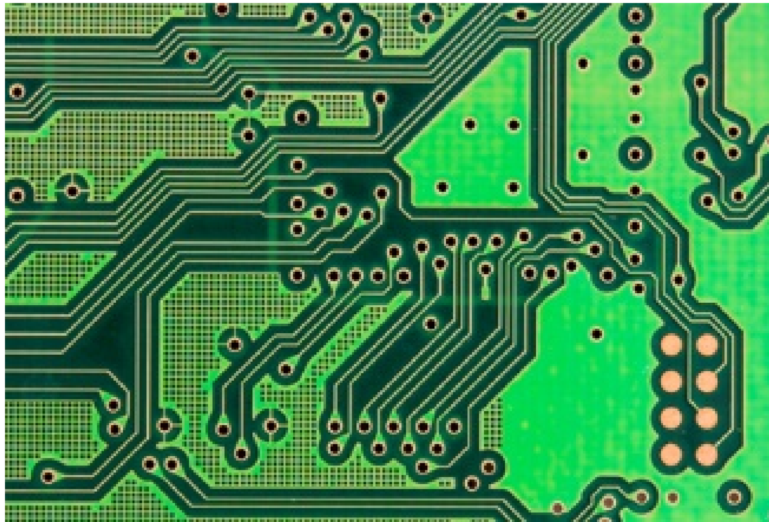
Circuit boards in Electronics

Are an integral part of electronics

Needed for a base to print the electronics on

Provide support and structure



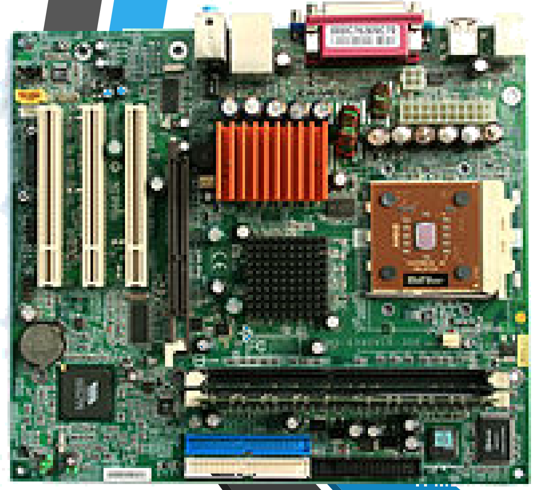


$$C = \frac{\varepsilon_0 K A}{d}$$

Capacitors and Dielectrics

Capacitors store charge in the electric field between two charged plates and dielectrics increase capacitance

In microelectronics, the components of the circuit board act as the charged plates to parasitically store the charge



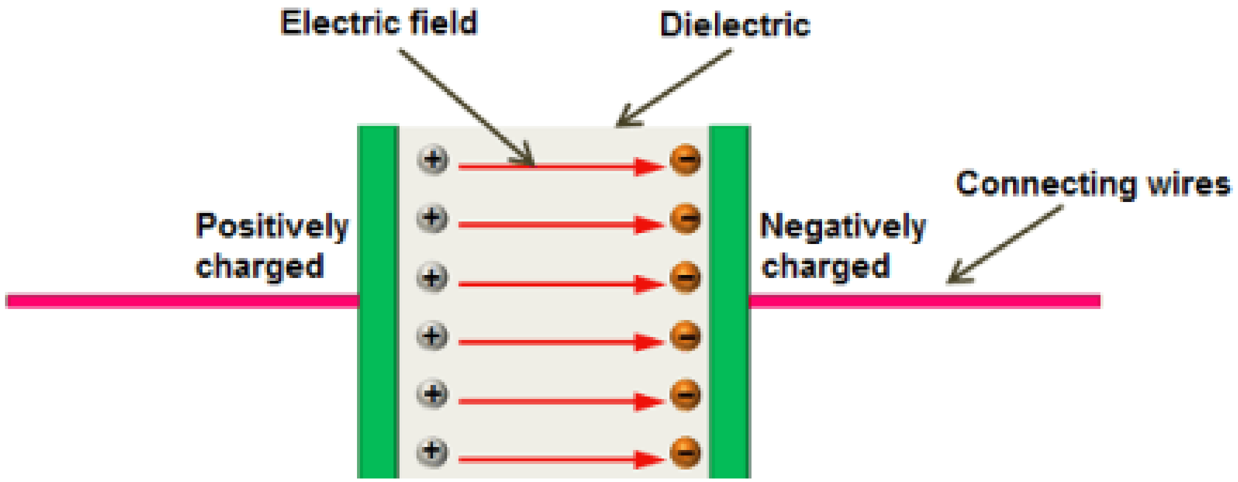


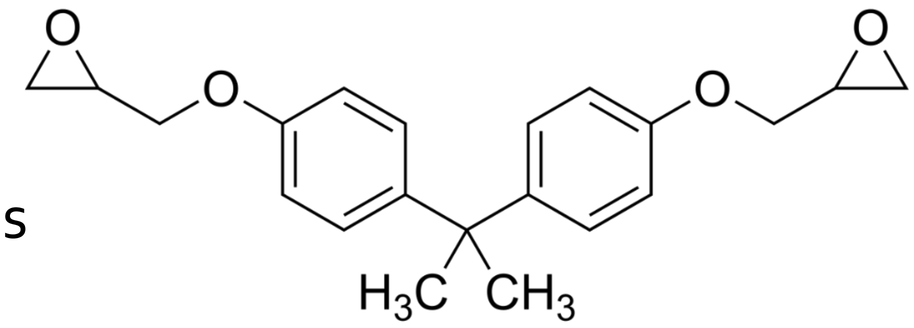
TABLE 17–3 Dielectric constants (at 20°C)

Material	Dielectric constant K	Dielectric strength (V/m)
Vacuum	1.0000	
Air (1 atm)	1.0006	3×10^6
Paraffin	2.2	10×10^6
Polystyrene	2.6	24×10^6
Vinyl (plastic)	2–4	50×10^6
Paper	3.7	15×10^6
Quartz	4.3	8×10^6
Oil	4	12×10^6
Glass, Pyrex	5	14×10^6
Rubber, neoprene	6.7	12×10^6
Porcelain	6–8	5×10^6
Mica	7	150×10^6
Water (liquid)	80	
Strontium titanate	300	8×10^6

Epoxy Resins in Circuit Boards

Common in industry for printed circuit boards

Cheap, easy to make, and strong



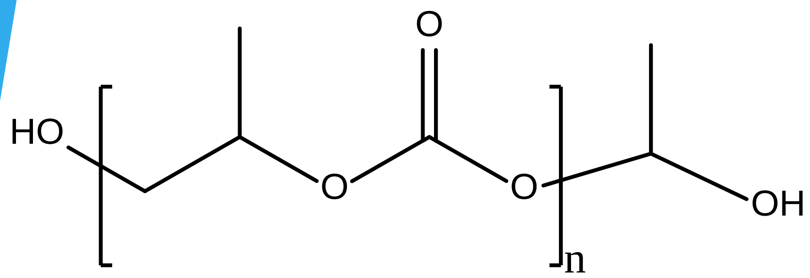
Bisphenol A diglycidyl ether
(BPADGE)

Our Plan

To make a low dielectric material by creating a nano porous epoxy resin (to maximize air in the film)

Pumice stone→
(A strong porous material)

Overview



Poly-Propylene Carbonate (PPC)

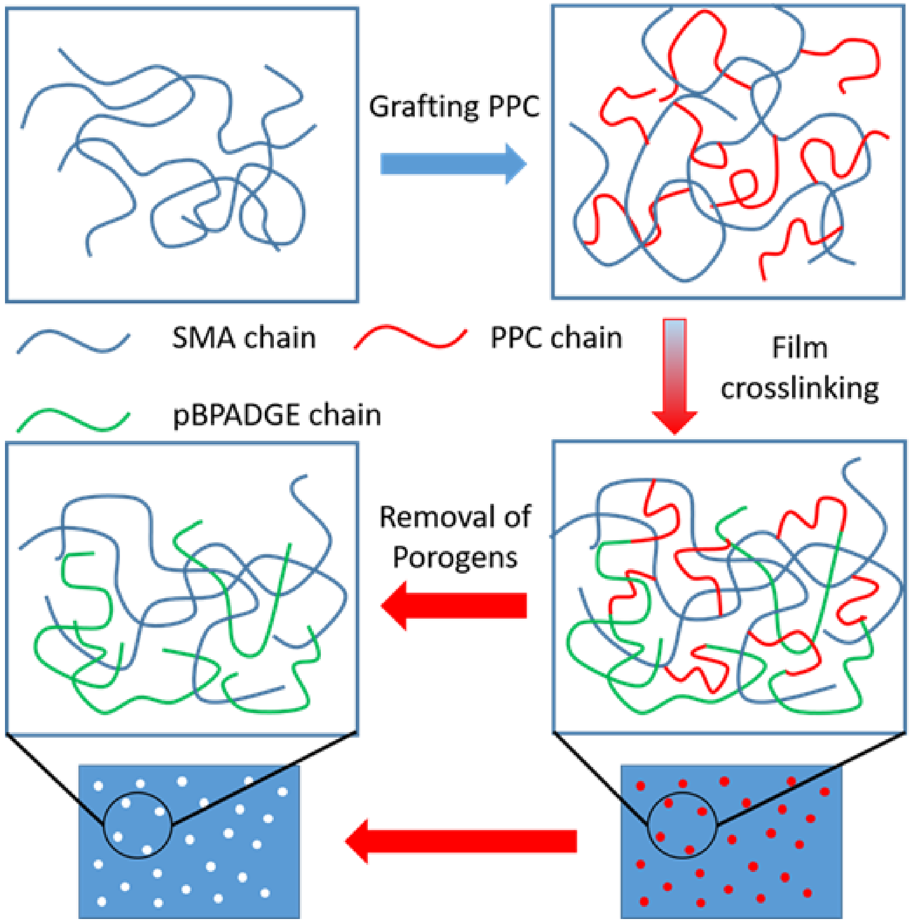
Porogen

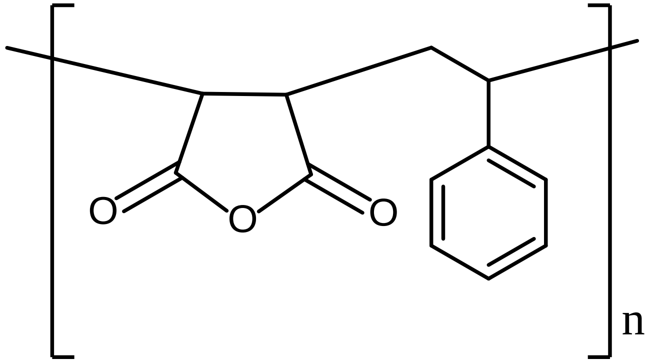
Multiple chain lengths

n=20

n=10

Shorter chain lengths reduce steric hindrance





Styrene Maleic Anhydride (SMA)

Multiple Styrene to Maleic Anhydride ratios used:

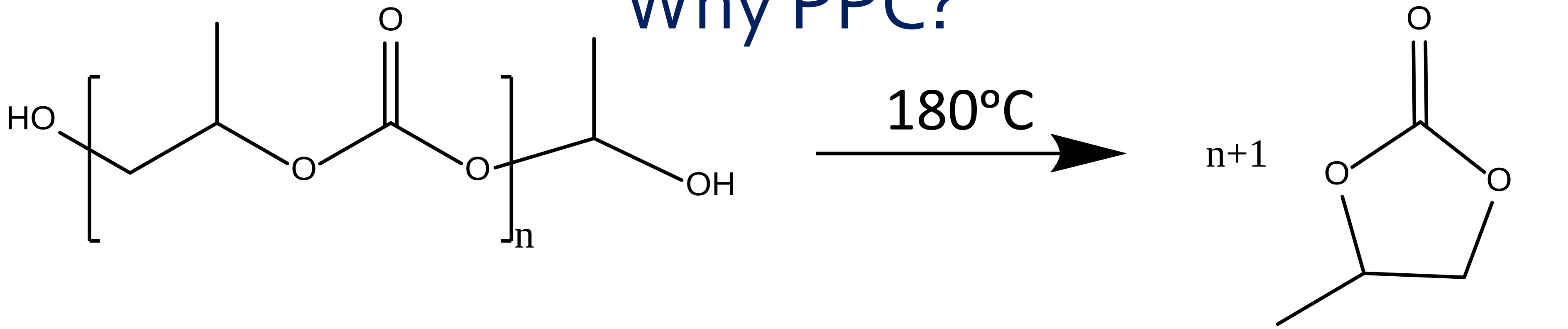
4:1

2:1

Ratio controls how much porogen can be incorporated

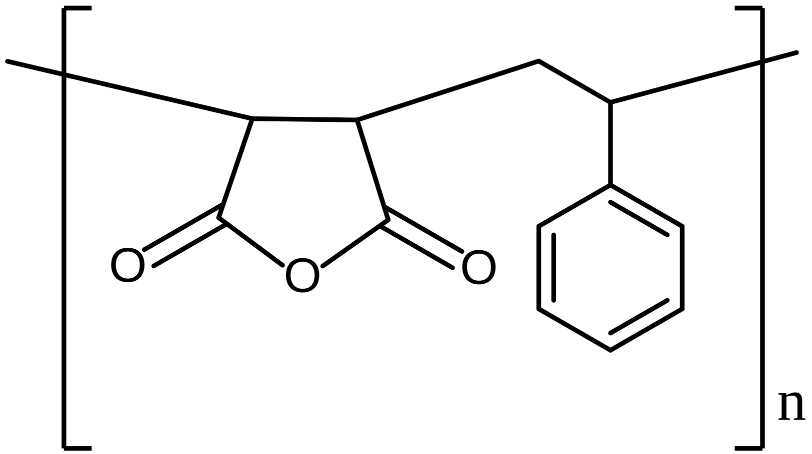
Maleic Anhydride is the bonding site, so increasing this ratio (2:1) allows more incorporation of ePPC

Why PPC?



Propylene Carbonate
(Volatile)
Evaporates to create pores

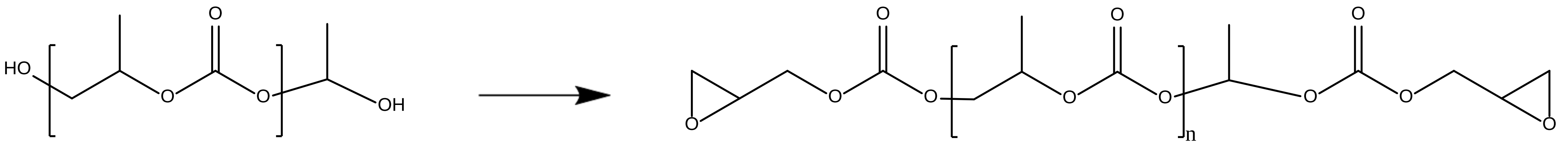
Why SMA?



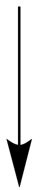
Crosslinking agent that improves mechanical properties of epoxy resin

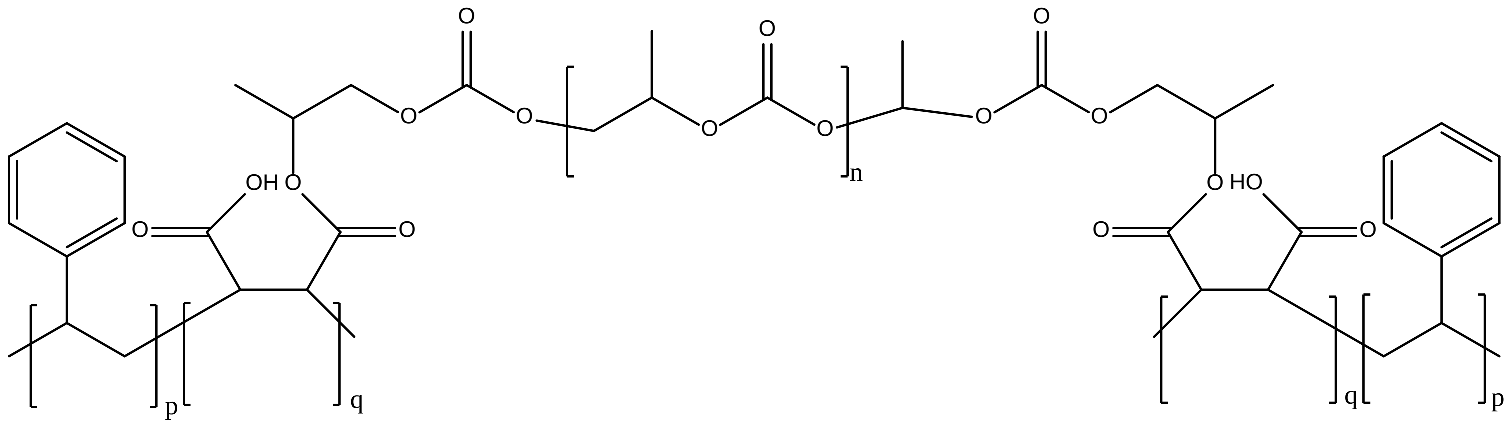
Acts as grafting site for PPC and locks porogen in place before phase segregation can occur

Reaction Mechanism



The PPC is functionalized and then grafted onto an SMA chain

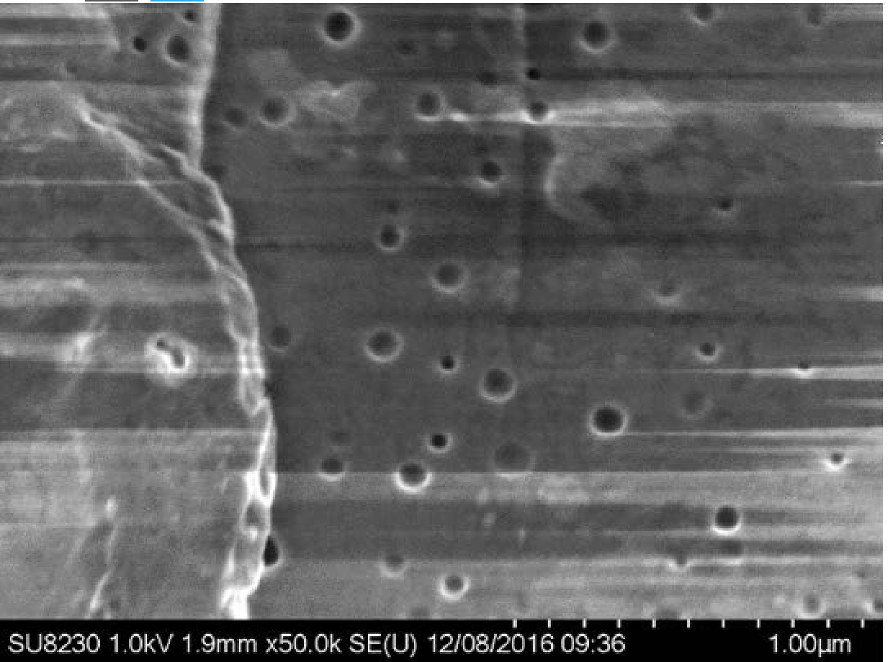




Why the Grafting Instead of Just Mixing

To spread out the pores evenly and prevent phase segregation (clumping)

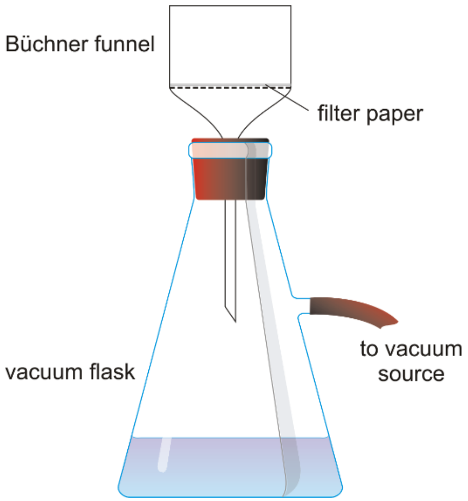
This preserves mechanical properties



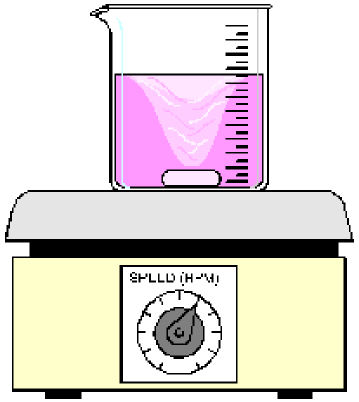
← Not This large Pores as a result of clumping

This→ Evenly spread pores

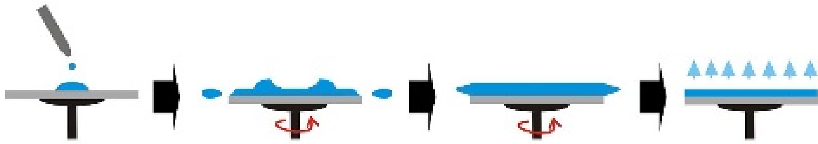
Process



Mixture precipitated in Hexane



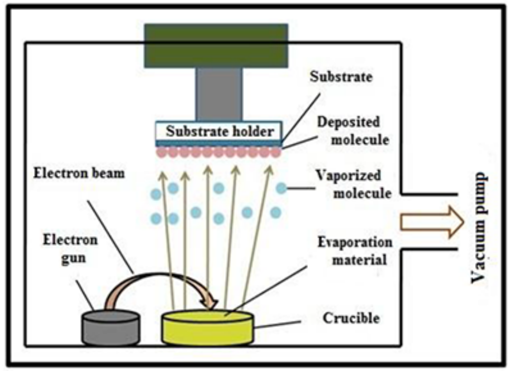
Mixed with BPADGE



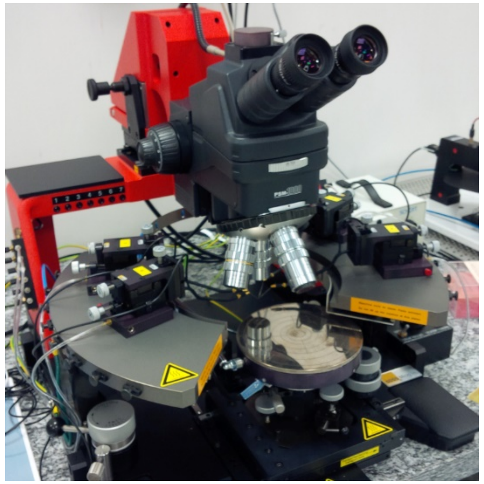
Spin coated onto wafer

Process (continued)

Samples cured on hot plate (activates porogen)



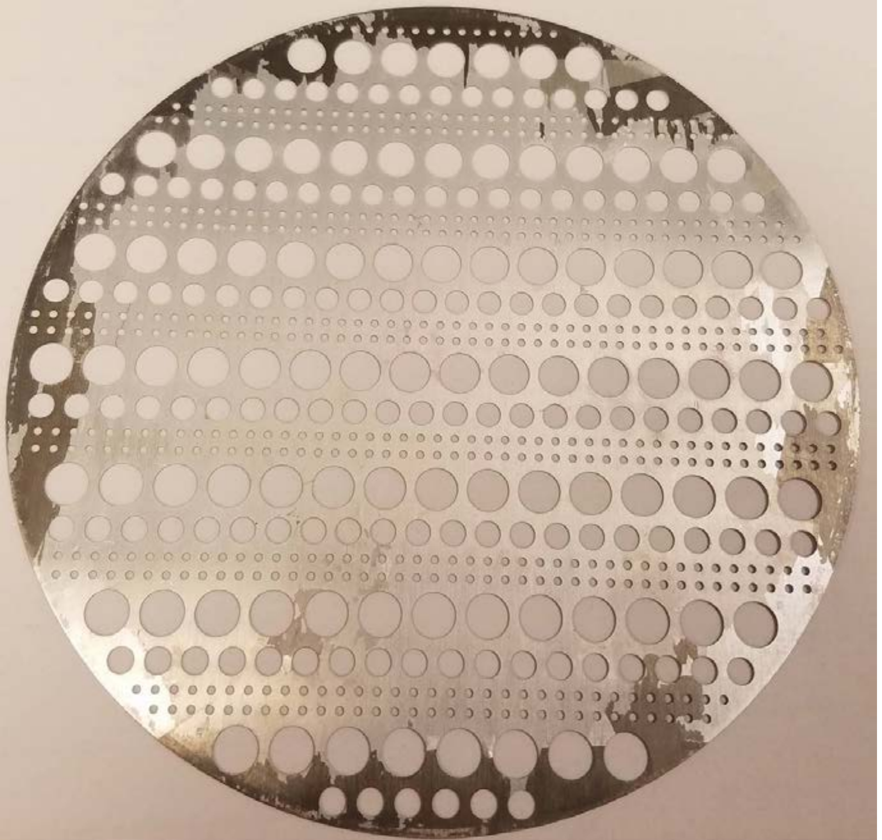
Made into capacitors with e-beam evaporator (deposits Al)



Capacitance is measured

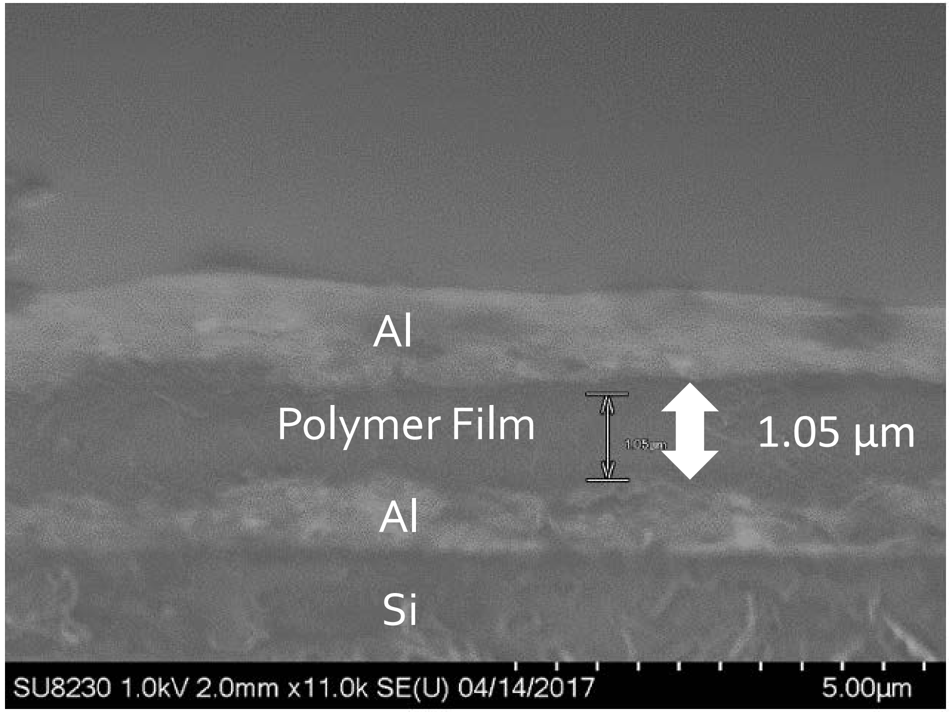
The Capacitor (Parallel Plate)

The Capacitor



←Shadow mask for Al deposition

Parallel plate capacitor →



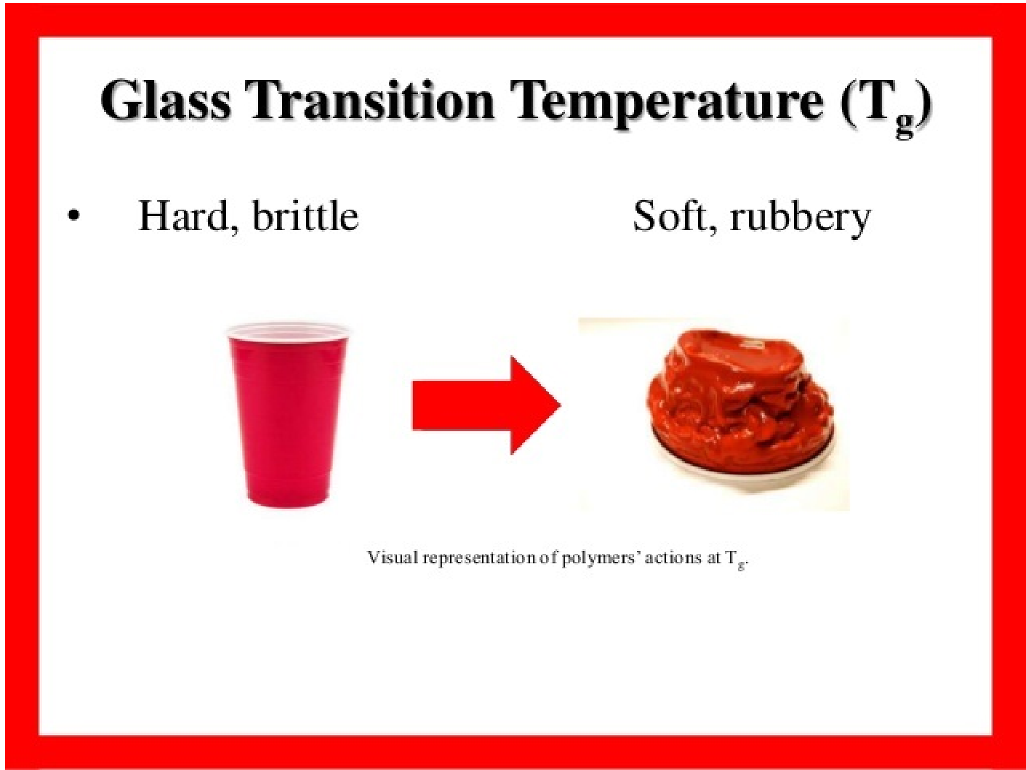
Objective

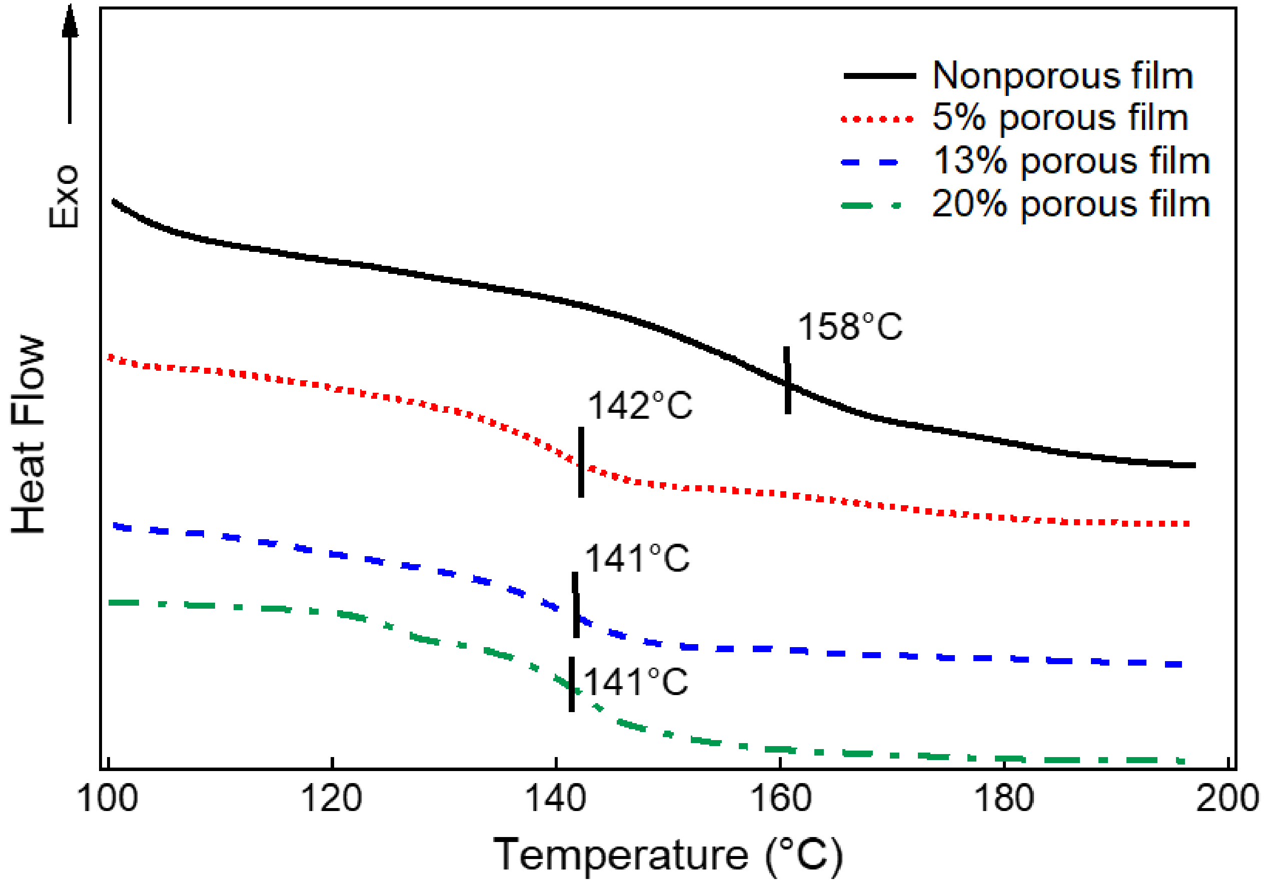
Studying the effects that increasing amounts of pores have on the dielectric constant and glass transition temperature of the material

Glass Transition Temperature

The temperature that epoxy resin transition from a hard, glassy substance to a soft, rubbery substance

← DSC
(Differential Scanning Calorimeter)
used to measure the Tg





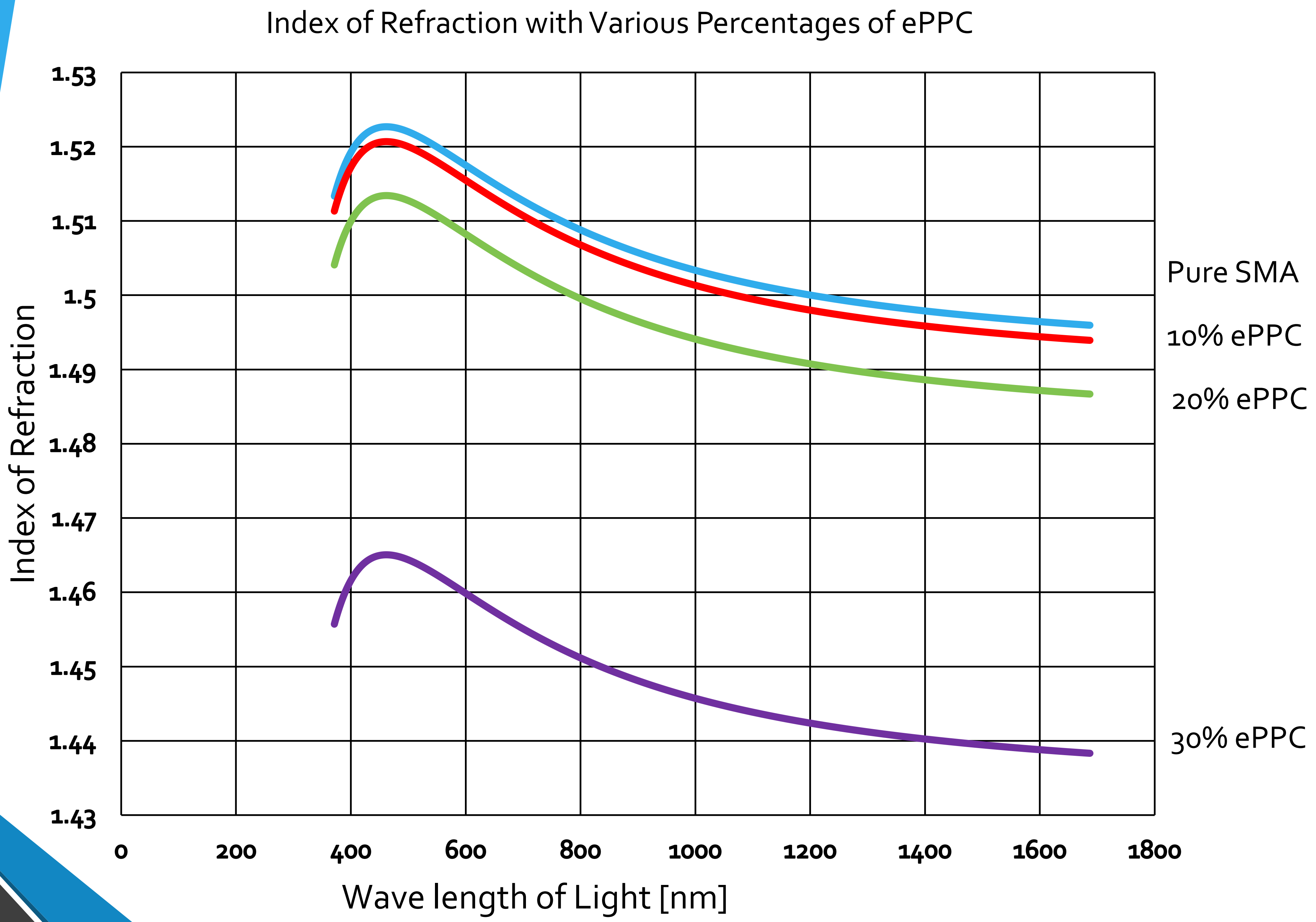
Glass transition temperature decreases with increasing number of pores caused by a decrease crosslink density

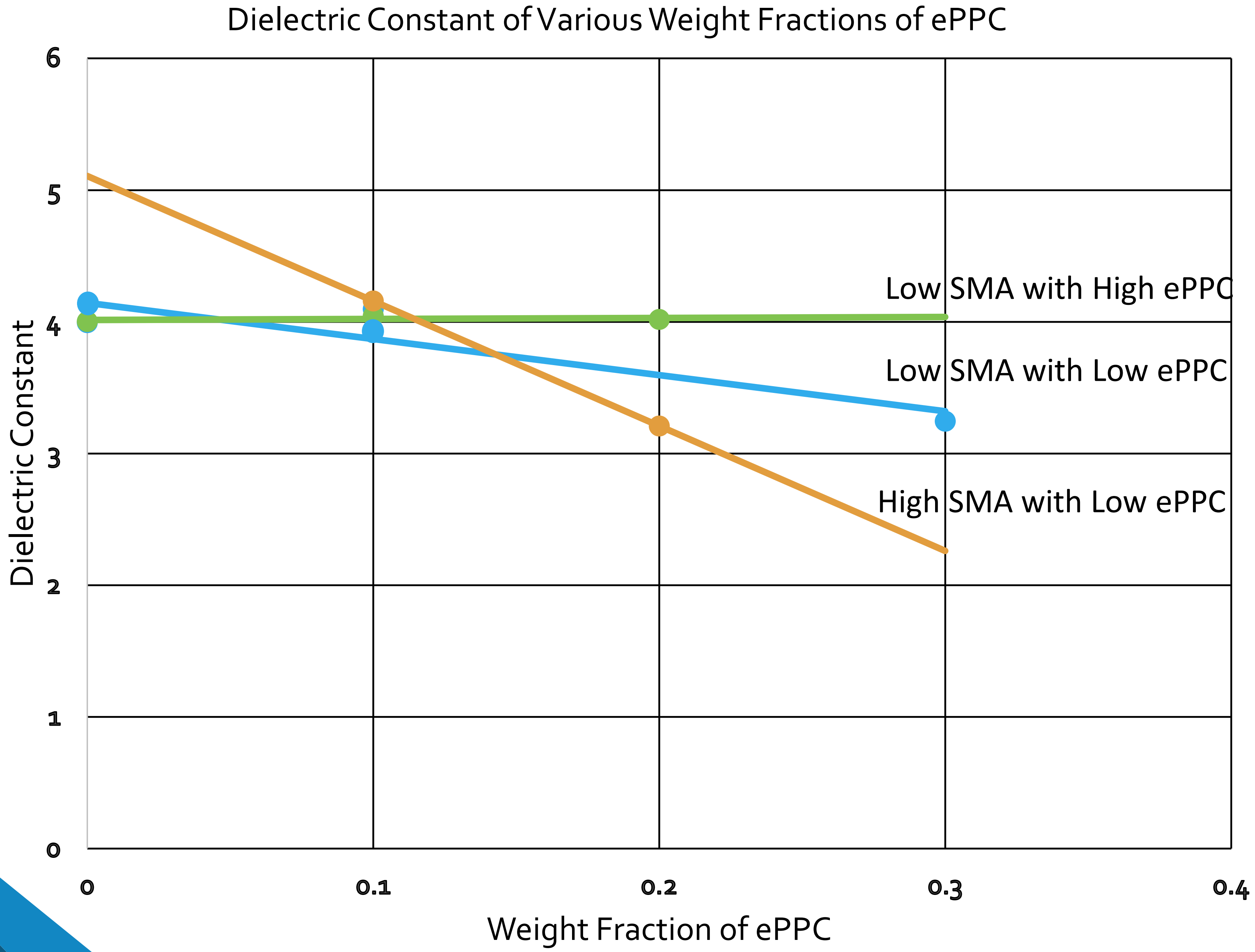
Woollam Ellipsometer

Index of Refraction

This Index is closely linked to the relative permeability of the object (indicates the dielectric constant of the substance)

$$n = \frac{c_{vacuum}}{c_{lens}} = \frac{\text{velocity of light in vacuum}}{\text{velocity of light in lens}}$$


Index of Refraction with Various Percentages of ePPC
Index of Refraction
1.53
1.52
1.51
1.5
1.49
1.48
1.47
1.46
1.45
1.44
1.43
0
200
400
600
800
1000
1200
1400
1600
1800
Wave length of Light [nm]
Pure SMA
10% ePPC
20% ePPC
30% ePPC



Lines show trend with linear progression

Future Works

Investigate distribution and integrity of the pores

Image nanoporous structure and determine the distribution of pore size

Measure mechanical properties to determine the effect of increasing porosity

Increase grafting ratio beyond 40% ePPC

Mix with free SMA to increase cross linking sites for improved Tg

Acknowledgments

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